DOUGLAS-FIR IN EASTERN NEBRASKA:
A Provenance Study

Ralph A. Read and John A. Sprackling

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An 11-year field test of rangewide provenances of Douglas-fir in eastern Nebraska revealed that height and growth rate are inversely correlated with latitude of origin. Progeny of seed origins from Arizona and New Mexico grew two to three times faster than those from northern Colorado, western Montana, and northern Idaho. Arizona and New Mexico origins, which start growth earlier in spring and cease growth later in fall than northern origins, are recommended for Christmas trees. Slower growing but winter-hardy northern Colorado origins are recommended for all other types of planting.

Keywords: *Pseudotsuga menziesii,* provenances, growth, needles, Christmas trees, ornamentals.

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always read and follow the directions on the pesticide container.

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[1]*Central headquarters maintained at Fort Collins, in cooperation with Colorado State University; research reported here was conducted at the Station's Research Work Unit at Lincoln, in cooperation with the University of Nebraska.*

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Preface

This provenance study is one of a dozen experimental plantations of various tree species established on the Horning State Farm near Plattsmouth, Nebraska, which is administered by the Department of Forestry of the University of Nebraska. The USDA Forest Service, through its Rocky Mountain Forest and Range Experiment Station Research Work Unit at Lincoln, cooperates with the Nebraska Agricultural Experiment Station in research conducted on this experimental area.

The specific purpose of this work is to find and develop better adapted trees for use in all kinds of plantings, environmental and commercial, throughout Nebraska and the Central Plains. Such provenance studies of different species provide plants of known origin for evaluation of adaptability and genetic variation, and for selection, propagation, and breeding for resistance to disease and insect pests. Studies have been reported in publications listed below.

The diversity of tree planting materials under study at this and many other locations in the Plains was made possible through cooperation in a Regional Tree Improvement Project (NC-99, formerly NC-51) of the North Central States Agricultural Experiment Stations.

Credits are due Jonathan W. Wright, Professor of Forestry, Michigan State University, for initiating the Regional study and providing the planting stock, and to Walter T. Bagley, Associate Professor of Forestry, University of Nebraska, for cooperation in planting and maintenance of the plantations.

Published Reports on Provenance Studies

1971. Scots pine in eastern Nebraska: A provenance study. USDA For. Serv. Res. Pap. RM-78, 13 p. by Ralph A. Read.

1975. Jack pine provenance study in eastern Nebraska. USDA For. Serv. Res. Pap. RM-143, 8 p. by John Sprackling and Ralph A. Read.

1975. Red pine provenance study in eastern Nebraska. USDA For. Serv. Res. Pap. RM-144, 7 p. by John A. Sprackling and Ralph A. Read.

1976. Douglas-fir in eastern Nebraska: A provenance study. USDA For. Serv. Res. Pap. RM-178, 10 p. by Ralph A. Read and John A. Sprackling.

1976. Eastern white pine in eastern Nebraska: A provenance study of southern Appalachian origins. USDA For. Serv. Res. Pap. RM-179, 8 p. by John A. Sprackling and Ralph A. Read.

1976. Austrian (European black) pine in eastern Nebraska: A provenance study. USDA For. Serv. Res. Pap. RM-180, 8 p. by Ralph A. Read.

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DOUGLAS-FIR IN EASTERN NEBRASKA: A Provenance Study

Ralph A. Read and John A. Sprackling

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the most important commercial timber tree in the United States. The species has been introduced in many countries around the world for its exceptional commercial value. In the Great Plains, however, Douglas-fir is not planted for timber purposes, but as a tree for the amelioration of environment and for use as Christmas trees. The Great Plains region of North America needs conifers for protection and for ornamental purposes. If seed sources are carefully chosen, Douglas-fir trees can help fulfill these needs in selected locations. This study is one of a number of provenance tests of various conifers, whose objective is to identify better-adapted seed origins of trees for planting in the central Great Plains.

Past Research

Douglas-fir has been successfully introduced in Europe. The interior (Rocky Mountain) variety has been planted in mountainous areas with severe climates; the Coastal form has been restricted to milder climates of England and parts of Germany (Frothingham 1909). In the United States, rangewide provenance tests east of the Rocky Mountains have consistently revealed that West Coast origins are highly susceptible to winter damage, and that southern Rocky Mountain origins grow fastest.

Natural stands of Douglas-fir (fig. 1) extend along the Pacific Coast eastward to the Cascade Mountains, from western British Columbia to central California (var. *menziesii*), and along both sides of the Rocky Mountain Continental Divide from central British Columbia and Alberta into Mexico (var. *glauca*) (Little 1971).

Other geographic delineations within the species have been recognized, but there is some lack of agreement on them. Frothingham (1909) in an early report, divided the range into five silvical regions: (1) North Coast, (2) Sierra, (3) Northern Rockies, (4) Central Rockies, and (5) Southern Rockies. The first two of these comprise the area supporting the form known as var. *menziesii*, and the other three are in the regions where var. *glauca* is found.

Heit (1969) prefers to recognize three forms of Douglas-fir, based upon nursery studies of seedlings from rangewide sources: (1) Pacific Coast form *viridis*, same as var. *menziesii* west of the Cascades; (2) the continental inland form *caesia* and *caesia-glauca* mixtures in the northern Rocky Mountains; and (3) form *glauca* in the central and southern Rocky Mountains.

Wright et al. (1971), in a rangewide study, delineated 8 to 10 geographic areas based on performance of seedlings in a Michigan nursery, and on subsequent performance in 3- to 8-year-old provenance plantations in Michigan and Nebraska. Some of his groups were very similar to Frothingham's pattern, while others were not. In Wright's tests, Arizona and New Mexico sources grew tallest and had bluer foliage than other sources at 7 years of age, but these fast-growing origins were also damaged by winter cold in the Michigan plantings. Origins of var. *menziesii* from west of the Cascades suffered extreme winter injury, and many of them died in the nursery.

Heit (1969) found that, of 11 interior origins tested in his New York nursery, those from the Coconino National Forest in Arizona and the Carson National Forest in New Mexico grew fastest and had the bluest foliage. A Montana origin from the Lewis and Clark National Forest grew slowest, while Colorado origins were intermediate. He concluded that southern origins grew later into the summer when annual growth ceased for others, and that frost damage to these origins was light and temporary.

A Pennsylvania test of 19 origins from the Pacific Coast to the Rockies (Byrnes et al. 1958) resulted in 55 percent mortality for western Washington and Oregon origins, compared to 21 percent for those from Colorado and New Mexico. Yet, growth rates of surviving Pacific Northwest trees slightly exceeded interior origins. Late spring frosts damaged southern and northern interior origins, but they recovered rapidly and grew well. In contrast, 54 percent of the Pacific Northwest trees suffered winter injury compared to only 5 to 9 percent of interior origins.

Gerhold (1966) tested 67 of Wright's origins in a nursery near Potters Mills, Pennsylvania. West Coast origins were severely damaged by

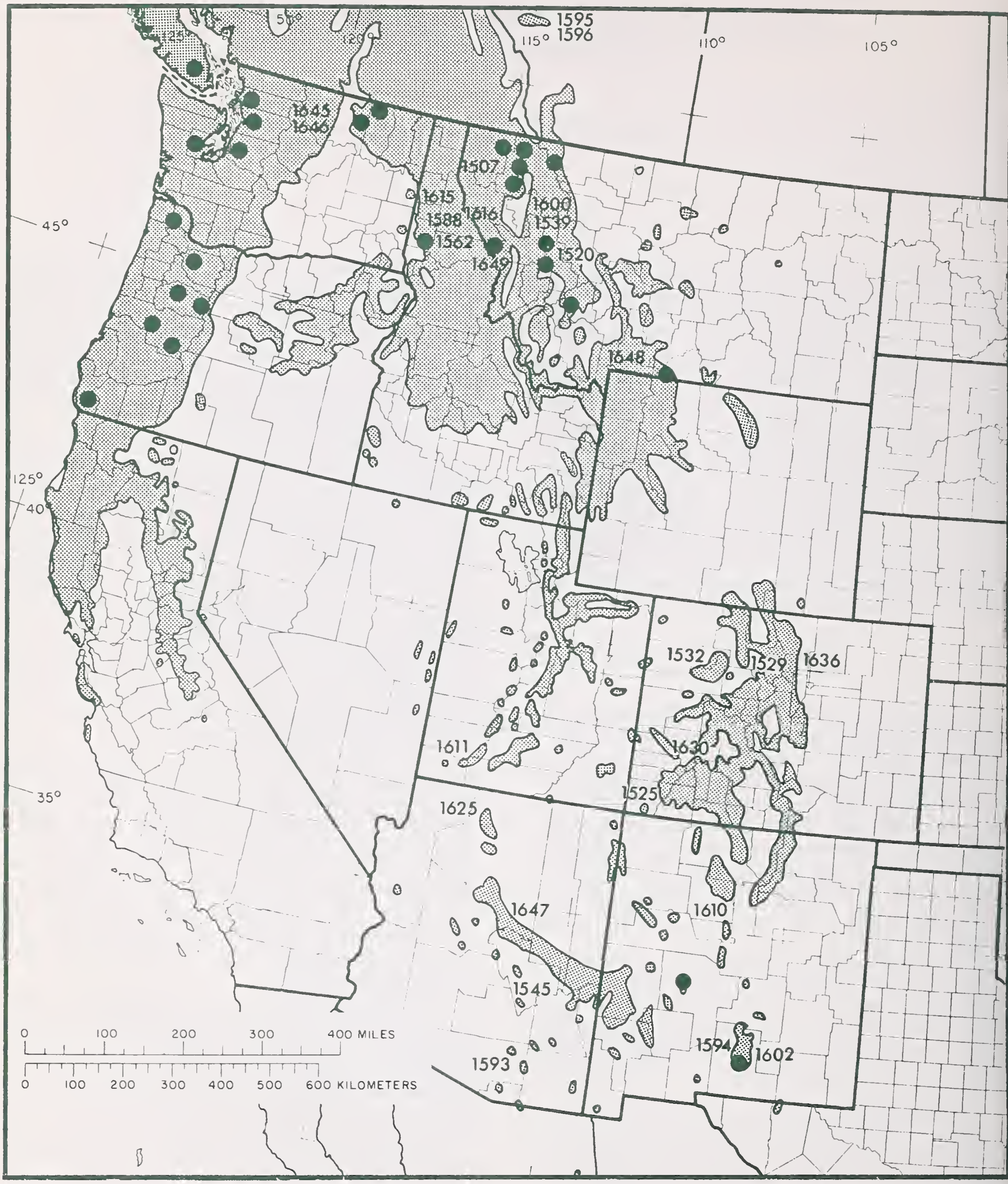

Figure 1.—Natural distribution of Douglas-fir, and provenances tested in eastern Nebraska. Origin numbers denote those that survived; black circles, those that died in first 3 years.

winter cold, but the survivors were tallest of all origins at age 3. As in Wright's study, the Arizona and New Mexico origins outgrew other interior origins, but suffered more winter injury.

The performance of Douglas-fir origins in eastern Nebraska reported here updates the first report by Wright et al. (1971). The 55 origins tested in Nebraska have had 6 additional years' growth, and we have new information on spring growth flushing, winter damage to terminals, needle lengths, and cone production.

Materials and Methods

Seeds were collected by U.S. Forest Service and other personnel from 128 natural stands throughout the range of the species in United States and Canada. These seeds were sown in spring 1962 under the direction of Jonathan Wright in a Michigan State University nursery near East Lansing. One year later, 30 to 60 seedlings each of 55 origins (table 1) were sent via air freight to Lincoln, Nebraska, where they were lined-out in holding beds on the East Campus of the University. In spring 1964, the 1+1 seedlings were dug, potted, and lined-out again at the same location to increase size for field planting.

In spring 1965, they were field planted as 1+1+1 stock at the Horning State Farm near Plattsmouth, Nebraska. The plantation is located on a ridgetop of silt loam soil derived from loess, at 41° north latitude, 96° west longitude, and 1,100 feet (335 m) elevation. The growing season averages 170 days, and mean annual precipitation is 30 inches (76 cm), of which 75 percent falls during the growing season. Seedlings were planted in one-tree randomized plots spaced 12 feet (3.6 m) apart, in rows 12 feet apart. Eastern redcedar (*Juniperus virginiana* L.) fillers were planted for early protection between each Douglas-fir in the rows (but not between rows), to give a spacing of 6 by 12 feet (1.8 by 3.6 m).

The site was cultivated 1 year before planting. Simazine 80W at 4 pounds per acre was sprayed on both sides of each tree row after planting to control weeds, and once each spring for 5 years thereafter. The plantation was mowed between rows during the growing season. Dead trees were replaced with extra trees and by consolidating the plantation into five rows in 1966. The trees were checked several times each year for insects, diseases, and other injury. Heights were measured annually from 1966, except for 1972. The juniper fillers were removed in spring 1974 to prevent crowding.

Trees were rated on two dates in spring 1974, four dates in spring 1975, and once in spring 1976 as to the developmental stage of buds, and growth of new shoots and needles. An estimate of the sequence in which the different origins start spring growth was obtained by rating each tree on a scale of 1 to 5. The number scale corresponded to five stages of development, ranging from dormant buds (no growth) to well-advanced shoot and needle growth. All trees were rated in 1 day. Terminal dieback was noted in late winter, and late spring frost damage was scored 3 days after it occurred. Average needle length was computed from measurements of five needles collected from lateral branches on the south side of each tree. Cones were counted in fall 1975.

The arrangement of seed origins in the accompanying tables is by geographic area, starting on the Pacific Coast, then to the northern Rocky Mountains, central Rockies, and southern Rockies. The dashed line that separates data in the tables indicates caution. Few trees survived from origins listed above the line; hence their performance data, though included here for comparison, are less reliable than data below the line.

Results and Discussion

Seedling Survival

Mortality in the temporary holding beds at Lincoln was 76 percent the first year. At the end of the second year as potted seedlings, total mortality was 89 percent. All seedlings of origins from coastal western Washington and Oregon had died. Very few of the seedlings from northern Idaho, western Montana, eastern Washington, and Alberta, Canada origins survived after 3 years in the field (table 1). Survival of central and southern Rocky Mountain origins was 20 percent, with Arizona and New Mexico origins consistently best.

We recognize the limitations in deriving reliable conclusions from performance of the few surviving trees representing the northern Rocky Mountain and coastal sources. These are delineated above the dashed line in table 1. In retrospect, we attribute the excessive mortality in all origins during the first 2 years in the holding beds to a combination of factors:

(1) transplanting very small seedlings into heavy-textured prairie soil,
(2) lack of shading and wind protection during extremely hot and cold weather, and
(3) lack of adequate moisture at critical times during the growing season.

Normally, Douglas-fir seedlings are protected from extreme insolation and wind during their first few years in Plains nurseries. Need for shading very small seedlings is pointed out by Ryker and Potter (1970) in an Idaho seed spot test,

Table 1.--Douglas-fir tested in an eastern Nebraska field plantation, with seed origin, survival records, and height growth, 1968-75

Michigan State Univ. Origin No.	State or Province where seed originated		Latitude	Longitude	Elevation		Seedlings				Height growth		
							Received	Failed[1]	Planted	Survived	Mean ann. 1968-75	11-yr field	Plantation mean
			°N	°W	ft	m	- - - - -	No.	- - - - -		ft	ft	%
PACIFIC COAST (var. *menziesii* or form *viridis*)													
1619	OREG	Brookings	42.0	124.2	162	49	60	x					
1613	OREG	Oakridge	43.7	122.5	3000	914	60		3	0			
1622	OREG	Cottage Grove	43.8	123.0	675	206	30		1	0			
1585	OREG	Sisters	44.3	121.8	3500	1067	50	x					
1618	OREG	Cascadia	44.4	122.7	800	244	60	x					
1621	OREG	Molalla	45.2	122.2	100	30	60	x					
1624	OREG	Jewell	45.8	123.4	700	213	60		4	0			
1627	WASH	Shelton	47.2	123.4	320	98	60		2	0			
1623	WASH	Enumclaw	47.2	122.0	1308	399	60	x					
1617	WASH	Granite Falls	48.1	122.0	600	183	30	x					
1620	WASH	Camano	48.2	122.3	50	15	30	x					
1634	VANC	Cowichan Lake	48.8	124.0	600	183	30	x					
1645	WASH	Fish Lake	48.6	119.7	2000	610	60		7	4	1.1	10.4	81
1646	WASH	Buck Mountain	48.4	119.8	5000	1524	30		5	1	1.1	8.9	70
NORTHERN ROCKY MOUNTAIN (var. *glauca* or forms *caesia* and *glauca*)													
1556	WASH	Curlew	48.9	118.8	4100	1250	30	x					
1651	WASH	Omak	48.6	119.5	2500	762	60		2	0			
1615	IDAHO	Coeur d'Alene	47.7	116.8	2400	732	30		3	2	1.1	9.2	72
1588	IDAHO	Wallace	47.5	116.0	3000	914	60		9	7	1.0	8.8	69
1562	IDAHO	Clarkia	47.0	116.1	4500	1372	30		5	2	.5	4.5	35
1573	IDAHO	Moscow	46.6	116.8	2500	762	60	x					
1507	MONT	Libby	48.4	115.5	3800	1158	30		1	1	1.2	9.8	77
1517	MONT	Libby	48.4	115.2	4000	1219	30		1	0			
1650	MONT	Whitefish	48.5	114.7	3500	1067	30		1	0			
1519	MONT	Whitefish	48.4	114.7	4000	1219	60	x					
1521	MONT	Kalispell	48.2	114.5	3000	914	60		5	0			
1600	MONT	Spotted Bear RS	48.0	113.0	3680	1122	60		1	1	.8	6.4	50
1616	MONT	St. Regis	47.5	115.2	4000	1219	30		4	3	1.2	10.1	79
1603	MONT	St. Regis	47.2	114.8	5000	1524	60	x					
1649	MONT	Missoula	47.0	114.0	3500	1067	60		2	1	.9	8.0	62
1504	MONT	Missoula	47.0	113.8	6000	1829	60		1	0			
1520	MONT	Greenough	46.9	113.4	4000	1219	60		4	1	1.1	9.5	74
1506	MONT	Salmon Lake	47.2	113.2	5000	1524	60	x					
1539	MONT	Big Prairie RS	47.3	113.5	4600	1402	30		2	1	.4	3.6	28
1518	MONT	Stevensville	46.5	114.2	4500	1372	30	x					
1606	MONT	Butte	46.0	112.5	6500	1981	30		1	0			
1595	ALB	Kananaskis	51.0	115.0	4500	1372	60		2	1	.7	5.7	45
1596	ALB	Kananaskis	51.1	115.0	5000	1524	60		4	1	.5	4.2	33
1513	MONT	St. Mary	48.8	113.5	4480	1366	30	x					
1648	MONT	Big Timber	45.5	110.0	6000	1829	60		5	1	.4	3.4	27
1503	MONT	Absarokee	45.5	109.4	5600	1707	30		3	0			
CENTRAL AND SOUTHERN ROCKY MOUNTAIN (var. *glauca*)									-----	-----	-----	-----	-----[2]
1636	COLO	Boulder	40.2	105.5	8650	2637	30		14	7	1.0	8.6	67
1529	COLO	Kremmling	40.0	106.5	8000	2438	60		5	2	1.0	9.0	70
1532	COLO	Meeker	40.2	107.9	8200	2499	60		28	21	1.1	9.5	74
1630	COLO	Ouray	38.2	107.6	9100	2774	30		3	1	1.3	11.4	89
1525	COLO	Durango	37.5	107.8	8500	2591	60		12	8	1.4	12.7	99
1610	NEW MEX	Jemez RD	35.5	106.8	8500	2591	30		29	28	1.6	14.9	116
1546	NEW MEX	Magdalena	34.2	107.2	8200	2499	15	x					
1594	NEW MEX	Cloudcroft	33.0	105.8	8670	2643	30		11	8	1.7	15.1	118
1602	NEW MEX	Mayhill	32.9	105.4	7000	2134	60		37	34	1.7	15.7	123
1614	NEW MEX	Sacramento Mts.	32.7	105.7	8300	2530	60	x					
1611	UTAH	Panguitch	37.6	112.5	8250	2515	60		5	5	1.1	9.7	76
1625	ARIZ	Fredonia	37.0	112.5	9000	2743	30		12	8	1.2	10.7	84
1647	ARIZ	Long Valley	34.7	111.0	7000	2134	30		12	12	1.5	14.0	109
1545	ARIZ	Globe	33.3	110.7	7800	2377	30		5	4	1.6	15.6	122
1593	ARIZ	Mt. Lemmon	32.4	110.8	8400	2560	60		14	13	1.9	17.9	140
					Plantation total and means				265	178	1.4	12.8	100

[1]Origins failed during first 2 years in holding beds.
[2]Dashed line indicates caution. Few trees survived from the origins listed above the line, and performance data are less reliable than for origins listed below the line.

where 70 percent of shaded seedlings survived, compared to only 33 percent of unshaded seedlings. Moreover, planting stock for use in the Plains region is transplanted after seedlings are 2 years old, then grown another 2 years in the nursery before field planting. Past experience with Douglas-fir in the Plains has shown that larger, well-balanced stock (2+1 or 2+2) will give higher initial survival than we attained in our study.

Height and Growth Rates

Total height growth (table 1) was inversely correlated with latitude; trees from southern origins grew faster than those from northern origins. The correlation coefficient using origin means was r = −0.81; however, the northern origins showed considerably more scatter than the southern origins.

Growth curves (fig. 2) reveal that central and northern Rocky Mountain origins grew very slowly for 5 to 6 years after planting, but have since gradually accelerated. This contrasts with performance of various pine provenance tests in eastern Nebraska, which showed that pines normally increase their growth rate in the third year. At first the Douglas-fir planting site was rather open and exposed, but as the juniper filler trees and adjacent field tests of other species developed, the plantation received considerable protection from wind during both winter and summer.

All New Mexico and Arizona origins have grown rapidly since planting. Trees from Globe, Arizona (origin 1545), grew fastest through 1969, but since that time have suffered winter injury and repeated loss of terminals. Trees from Mt. Lemmon, Arizona (origin 1593), surpassed the Globe source and are now the tallest origin to date, averaging 17.9 feet after 11 years. The 13 trees of this Mt. Lemmon source range in height from 13.3 to 23.0 feet.

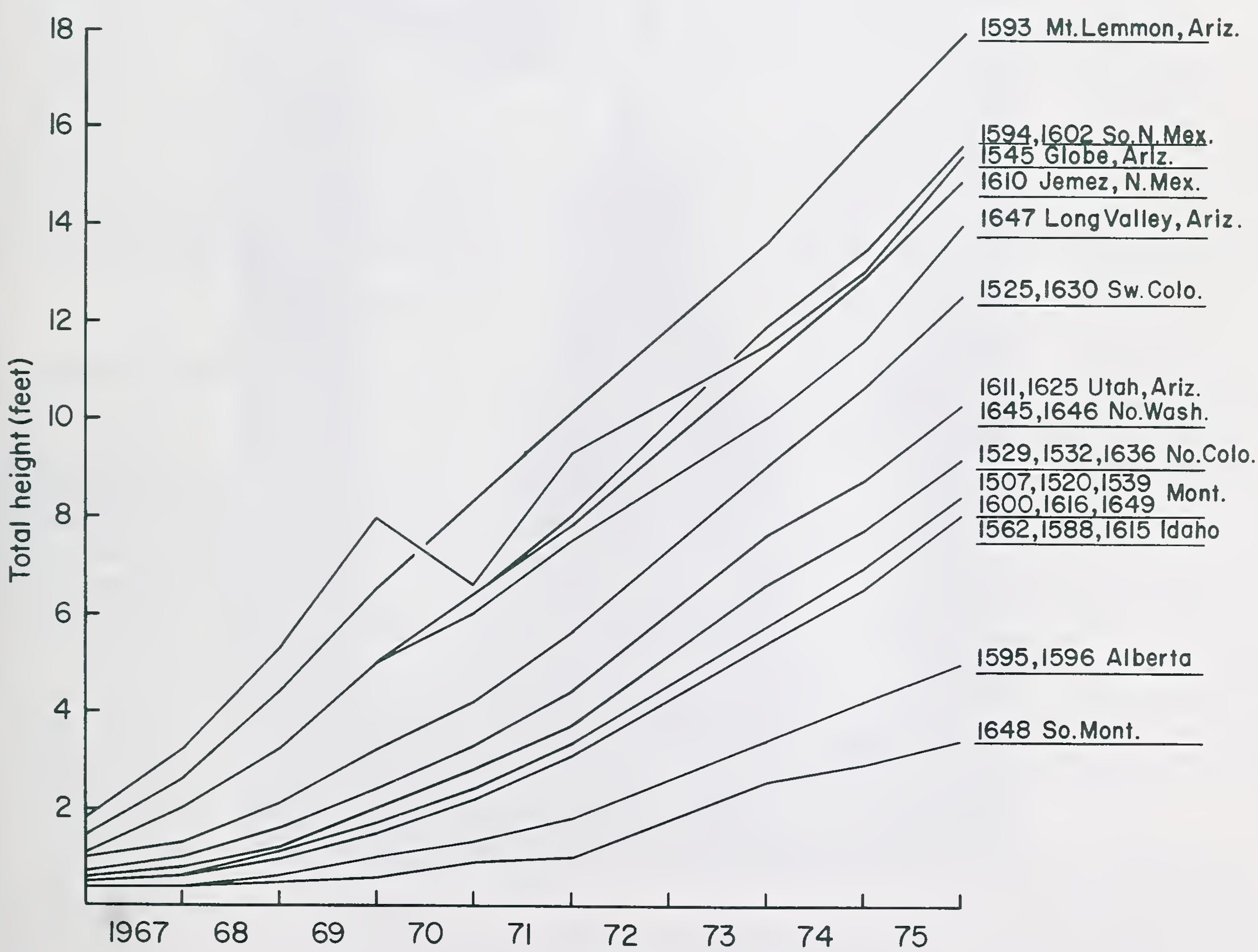

Figure 2.—Height growth curves for Douglas-fir origins (some grouped) after 11 years in an eastern Nebraska plantation.

Foliage Characteristics and Form

Needle lengths varied among and within origins (table 2), but showed no significant correlation with rate of height growth or latitude. The average needle length of most southern origins exceeded the plantation mean, however. Many New Mexico and Arizona trees had bluish-green foliage, but none of these origins was consistently blue green, as reported by some investigators. Northern Rocky Mountain trees invariably had green foliage. Branch angles, foliage densities, and compactness of crowns varied considerably among trees within the same origin. A number of individual trees of different origins have exceptional natural form, appearing as sheared Christmas trees (fig. 3).

Cone Production

First cones were observed in August 1975, after 11 years in the field. However, no staminate strobili have developed, and no measure of seed production or viability is available.

Of the Mt. Lemmon, Arizona origin 1593, 6 of 13 trees had cones ranging from 2 to 75 per tree, with a median of 7 to 8 cones (table 2); 3 of 28 trees of Jemez, New Mexico origin 1610 had 3 to 6 cones; and 1 of 4 trees of Fish Lake, Washington origin 1645 had 13 cones. Cones were produced only on the taller and larger crowned trees in the plantation.

Figure 3.—This tree (Meeker, Colorado origin 1532) has never been sheared, yet displays superior natural form for a Christmas tree. It is 9 feet tall after 11 years.

Table 2.--Douglas-fir tested in an eastern Nebraska field plantation, by seed origin: Needle length, cone production, stage of spring growth flush,[1] spring frost damage, terminal dieback, and the distribution by progressive stages of spring growth flush on May 9, 1974

Michigan State Univ. origin No.	Location[2]	Basis: Total trees	Needles: Average length	Needles: Plantation mean	Trees with cones	Cones per tree	Spring growth flush[1]: May 9 1974	Spring growth flush[1]: May 12 1975	Spring growth flush[1]: May 6 1976	Spring frost damage	Terminal dieback	Spring growth flush, May 9, 1974: No growth	New needles visible	Shoots-- <10cm	Shoots-- >10cm	Needles extended
		No.	*mm*	*%*	*No.*	*No.*				*%*	*%*	- - - - - *No. of trees*				- - - - -
1645	WASH (NC)	4	32	107	1	13	2.9	2.0	1.5	25	25		2	1	1	
1646	WASH (NC)	1	27	91	0		5.0	3.0	3.0	0	0					1
1615	IDAHO (N)	2	32	107	0		2.5	1.5	1.0	0	0		1	1		
1588	IDAHO (N)	7	32	107	0		2.0	1.5	1.3	14	0	4	1	1		1
1562	IDAHO (N)	2	28	94	0		2.5	1.5	1.0	0	0	1			1	
1507	MONT (W)	1	28	94	0		1.0	1.0	1.0	0	0	1				
1600	MONT (W)	1	28	94	0		2.0	1.0	1.0	0	0		1			
1616	MONT (W)	3	28	94	0		1.7	1.0	1.0	0	0	1	2			
1649	MONT (W)	1	28	94	0		2.0	3.0	2.0	0	0		1			
1520	MONT (W)	1	28	94	0		2.0	2.0	1.0	0	0		1			
1539	MONT (W)	1	31	104	0		4.0	2.0	2.0	0	0				1	
1595	ALBERTA	1	26	87	0		2.0	1.0	1.0	0	0		1			
1596	ALBERTA	1	25	84	0		3.0	1.0	1.0	0	0			1		
1648	MONT (S)	1	25	84	0		3.0	2.0	2.0	0	0			1		
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1636	COLO (N)	7	25	84	0		4.3	2.7	2.6	71	0			1	4	2
1529	COLO (N)	2	24	81	0		4.5	3.0	3.0	50	0				1	1
1532	COLO (N)	21	27	91	0		3.9	2.8	2.6	67	5			5	6	7
1630	COLO (SW)	1	33	111	0		2.0	1.0	1.0	0	0		1			
1525	COLO (SW)	8	34	114	0		4.5	3.5	2.9	75	0				4	4
1611	UTAH (SW)	5	30	100	0		3.2	2.3	2.1	25	0		1	2	1	1
1625	ARIZ (NW)	8	27	91	0		3.2	2.2	1.9	38	25		1	4	3	
1610	NEW MEX (N)	28	29	97	3	3-6	3.5	2.8	2.7	82	39		1	14	12	1
1602	NEW MEX (S)	34	30	100	1	4	3.5	2.6	2.3	53	30		3	17	13	1
1594	NEW MEX (S)	8	32	107	0		3.8	2.8	2.5	50	38			2	6	
1647	ARIZ (C)	12	32	107	0		4.6	3.2	3.0	92	58			1	4	7
1545	ARIZ (C)	4	40	134	0		4.4	3.4	3.2	100	100			1	1	2
1593	ARIZ (S)	13	30	100	6	2-75	4.1	2.9	2.9	77	38			4	5	4
Plantation means			30	100												

[1]Rating: 1.0 = latest (no development); 5.0 = earliest (advanced growth).
[2]NC = North Central; N = North; W = West; S = South; SW = Southwest; NW = Northwest; C = Central.
[3]Dashed line indicates caution. Few trees survived from the origins listed above the line, and performance data are less reliable than for origins listed below the line.

Spring Growth Flush

Bud burst and subsequent shoot and needle development showed wide variation by origin. New shoot and needle development were already well advanced on most Arizona and New Mexico origins before many of the northern origins broke dormancy (table 2). Colorado origins tended to be intermediate. This pattern was consistent for the 3 years, 1974 through 1976, although different spring temperature patterns in 1975 and 1976 narrowed the range of rating values.

Munger and Morris (1936) recorded similar bud burst activity in 13 coastal sources of Douglas-fir west of the Cascade Range and extending over only 3½° latitude from northern Washington to central Oregon. Bud burst was earliest on the southerly and low-elevation sources, and latest on those of northern Washington.

The Nebraska plantation grew for 11 years without spring frost damage. However on May 2, 1976, several weeks after growth had started on the earliest origins, the temperature dropped to 25° F (-4° C). New growth at the tips of lateral branches was killed on many, but not all, trees of southern origins (table 2). Only 2 of 27 trees of northern Rocky Mountain origins were frosted, and those were individuals that had flushed. In the Colorado and Utah origins, 30 of 51 trees showed frost damage. The heaviest damage occurred on Arizona and northern New Mexico origins with 48 of 57 trees frosted. Although the southern New Mexico origins from Mayhill and Cloudcroft had flushed and showed considerable new growth, only 22 of the 42 trees were frosted. Damage to new growth by this late frost appears temporary; new foliage was evident 4 days after the frost, on lateral buds which had not flushed earlier.

Steiner and Wright (1975) found this same relationship in a Kellogg, Michigan plantation at 12 years' age. Arizona, New Mexico, and Colorado origins flushed early and were highly susceptible to late spring frost, whereas origins from the northern Rockies of western Montana and northern Idaho flushed a month later and were not susceptible.

These observations indicate that the relationship between Douglas-fir phenology at this Nebraska latitude (41°) and latitude of origin is the opposite of that for ponderosa pine. In a central Nebraska nursery experiment, the northern origins of ponderosa pine seedlings from central and eastern Montana began spring growth several weeks **before** origins from New Mexico and Arizona.[2]

Terminal Dieback

Difference in time when terminals ceased growth and set buds were not measured. However, a possible result of such differences has been dieback of the terminals on 44 trees (about 44 percent) of the southern origins (table 2). Every Arizona and New Mexico origin showed damage on some trees, ranging from 25 percent for Fredonia, Arizona origin 1625 to 100 percent of Globe, Arizona origin 1545. This dieback did not begin until the trees were 5 to 6 years old, and averaged around 7 feet tall. Increased exposure of tops to winter winds may increase susceptibility, as it was noted that dieback increased significantly during the first winter after removal of the juniper filler trees.

Winter dieback has not yet caused mortality despite its recurrence on the same trees in successive winters. Strong lateral branches grow into dominant terminals the following growing seasons (fig. 4). Edgren (1970) found a similar pattern with 2+0 Douglas-fir seedlings in a Washington experiment. He selected undamaged seedlings and paired them with frost-damaged seedlings at Wind River nursery. No seedlings died, but frost-damaged seedlings developed multiple tops. His data suggested, however, that the percentage of trees with multiple tops decreases and that these effects do not persist.

Trees of southern origins apparently do not cease growth early enough to avoid frost damage in late fall. This agrees in part with Wright et al. (1971) who found that, among interior origins growing in Michigan and Pennsylvania nurseries, southern origins set buds latest, and therefore were winter damaged, while northern origins set buds earliest and were not injured. Campbell and Sorensen (1973) found this same relationship among West Coast origins of Douglas-fir, covering only a spread in latitude of 5° from southern Oregon to northern Washington. In well-established southern Michigan plantations, however, winter damage to Arizona and New Mexico origins has not been appreciable (Wright, personal communication).

Figure 4.— A tree from Long Valley, Arizona origin 1647 shows recovery from terminal dieback which occurred the previous winter.

Recommendations

This provenance test indicates that Pacific Coast origins of Douglas-fir (var. *menziesii*) cannot survive Nebraska winters, and therefore should not be planted here. The interior (Rocky Mountain) origins (var. *glauca*) exhibit large variations in survival, growth, and susceptibility to cold that are strongly correlated with latitude of origin. Of the northern Rocky Mountain origins tested, most survived poorly, grew slowly, and

[2] *Read, R. A. Genetic variation in 3-year-old seedlings of 80 provenances of ponderosa pine. (Unpublished manuscript on file at Rocky Mt. For. and Range Exp. Stn., Lincoln, Nebr.)*

thus are not recommended (fig. 5). Central Rocky Mountain origins have average survival and growth, yet are not affected by low temperatures. Southern Rocky Mountain origins survive well and grow very fast, but individual trees may suffer cold injury.

Major uses of this species in the central Great Plains are for ornamental plantings and for Christmas trees. The slower growing, but winter-hardy central Rocky Mountain origins may prove most successful for ornamental plantings in the long run. The Durango, Colorado origin 1525, which has above average survival, medium growth, and no winter damage, is well adapted for landscape plantings, greenbelts, and roadside parks. Central Rocky Mountain origins could be used for windbreaks, but are not recommended because faster growing species of pine and juniper are available for those purposes.

Southern Rocky Mountain origins are best suited for Christmas trees because they grow faster and have bluer foliage (fig. 6). Mt. Lemmon, Arizona origin 1593 and Mayhill, New Mexico 1602 are recommended for Christmas tree growers in eastern Nebraska. These trees averaged 6 feet tall after only 5 years in the test plantation. Crowns were dense and compact despite rapid growth. **These fast-growing but cold-susceptible origins should only be used in combination with other conifers, however.** When protection from wind is provided, these origins are considered a safe investment for a short-rotation crop. In selecting plantation sites it is therefore essential to avoid (1) frost pockets where spring frost damage could occur, and (2) windswept areas where terminal dieback could be serious.

Douglas-fir can be grown with greatest success in eastern Nebraska, although with irrigation it probably can be grown farther west in the State. For maximum survival, planting stock should have at least 8 to 12 inches top height and a well-balanced top-root system; such stock will normally be 2+1 or 2+2 age class from the best nurseries. Container stock of less age may be satisfactory, but research results are not yet available.

Figure 5.—After 11 years in the plantation, this tree from northern Idaho origin 1562 was less than 5 feet tall.

Figure 6.—Trees from Mt. Lemmon, Arizona origin 1593 (A) and Mayhill, New Mexico origin 1602 (B) illustrate the tallest origins after 11 years in the plantation. These origins produced many trees with excellent form as shown here.

Literature Cited

Byrnes, W., R., H. D. Gerhold, and W. C. Bramble.
1958. Douglas-fir varietal tests for Christmas tree plantations in Pennsylvania. Pa. Agric. Exp. Stn. Prog. Rep. 198, 6 p.

Campbell, R. K., and F. C. Sorensen.
1973. Cold-acclimation in seedling Douglas-fir related to phenology and provenance. Ecology 54:1148-1151.

Edgren, James W.
1970. Growth of frost-damaged Douglas-fir seedlings. USDA For. Serv. Res. Note PNW-121, 8 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Frothingham, E. H.
1909. Douglas-fir: A study of the Pacific Coast and Rocky Mountain forms. U. S. Dep. Agric. For Serv., Circ. 150, 38 p.

Gerhold, H. D.
1966. Growth and winter injury of Douglas-fir in a three-year-provenance demonstration. Northeast For. Tree Improv. Conf. Proc. 13:50-52.

Heit, C. E.
1969. Propagation from seed testing and growing Douglas-fir seeds from different sources. Am. Christmas Tree Growers J. 13(3):7-18.

Little, Elbert L., Jr.
1971. Atlas of United States trees. Vol. 1. Conifers and important hardwoods. U. S. Dep. Agric., Misc. Publ. 1146.

Munger, T. T., and W. G. Morris.
1936. Growth of Douglas-fir trees of known seed source. U. S. Dep. Agric., Tech. Bull. 537, 40 p.

Ryker, Russell A., and Dale R. Potter.
1970. Shade increases first-year survival of Douglas-fir seedlings. USDA For. Serv. Res. Note INT-119, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Steiner, Kim C., and Jonathan W. Wright.
1975. Douglas-fir Christmas trees: Variation in frost susceptibility and time of leafing out in Michigan. Mich. Acad. 7(2):185-190.

Wright, J. W., F. H. Kung, R. A. Read, W. A. Lemmien, and J. N. Bright.
1971. Genetic variation in Rocky Mountain Douglas-fir. Silvae Genet. 20(3):53-100.

Read, Ralph A., and John A. Sprackling.
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An 11-year field test of rangewide provenances of Douglas-fir in eastern Nebraska revealed that height and growth rate are inversely correlated with latitude of origin. Progeny of seed origins from Arizona and New Mexico grew two to three times faster than those from northern Colorado, western Montana, and northern Idaho. Arizona and New Mexico origins, which start growth earlier in spring and cease growth later in fall than northern origins, are recommended for Christmas trees. Slower growing but winter-hardy northern Colorado origins are recommended for all other types of planting.

Keywords: *Pseudotsuga menziesii*, provenances, growth, needles, Christmas trees, ornamentals.

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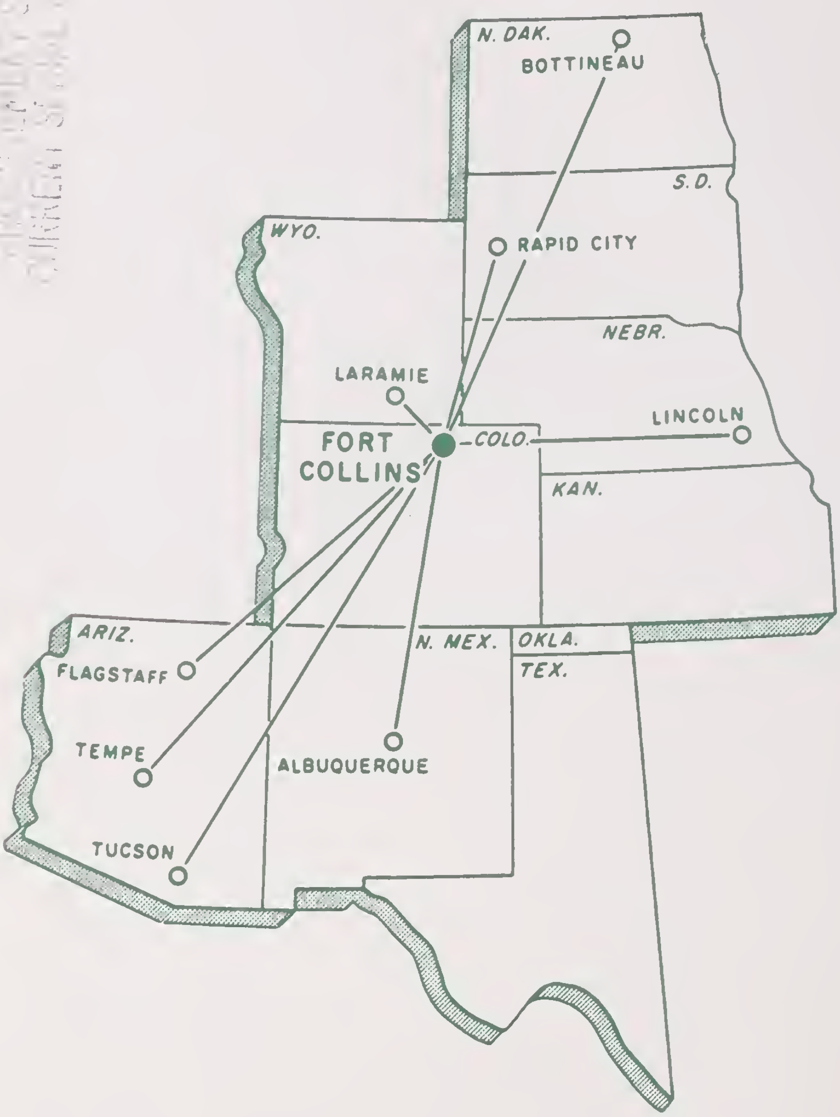
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